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**BROADBAND EMP TRANSIENT MEASUREMENT
PREEMPHASIS FILTER**

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February 1992

Final Report



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AIR FORCE SYSTEMS COMMAND
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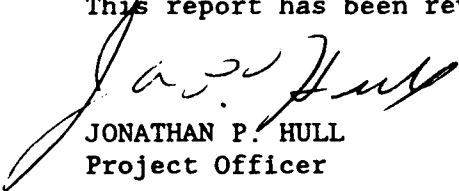
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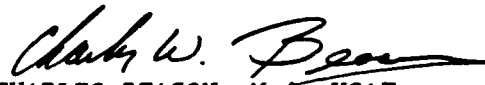
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INTRODUCTION

The broadband electromagnetic pulse (EMP) transient measurement preemphasis filter ("Filter") was developed to improve the signal-to-noise ratio in the high-frequency portion of single-pass EMP transient response measurements. The Filter was specifically developed for EMP applications, although the technique would benefit many other applications. Improvements of 12 dB and more have been observed at frequencies above 80 MHz with no loss of dynamic range in frequency components below that point. The technique is applicable for measurements which have greater low-frequency content than high-frequency content, and where one or more elements in the instrumentation chain have substantially smaller dynamic range than the source and sensor (e.g., fiber optic links).

BACKGROUND

Figure 1 shows a typical EMP transient data acquisition instrumentation channel. A sensor or current probe feeds a fiber optic link (FOL) which in turn feeds a transient digitizer such as a Tektronix 7912AD or LeCroy 6880. The dynamic range of a sensor or probe is typically >100 dB while the dynamic range of an FOL is around 34 dB. It has been difficult to acquire good high-frequency data in EMP current or field measurements, particularly with single-channel/single-measurement techniques, because link attenuation is always set to clear low-frequency components which are typically much greater in amplitude than low-frequency components. As a result the high-frequency components are pushed down into the link noise floor causing losses in signal-to-noise ratio of 12 dB and more. Poor dynamic range in the high end of EMP data is particularly troublesome because postprocessing emphasizes this region.

Figure 2 shows a raw frequency plot for a typical EMP current response measurement. The measurement was acquired with a Tektronix 7912AD digitizing oscilloscope using an EG&G SCP-1 current probe and a Nanofast OP-300 FOL. The frequency characteristics of the probe and link have not been unfolded for this plot. The noise floor of the link is shown on the plot (34 dB below the peak). The frequency components which fall below this noise floor are masked

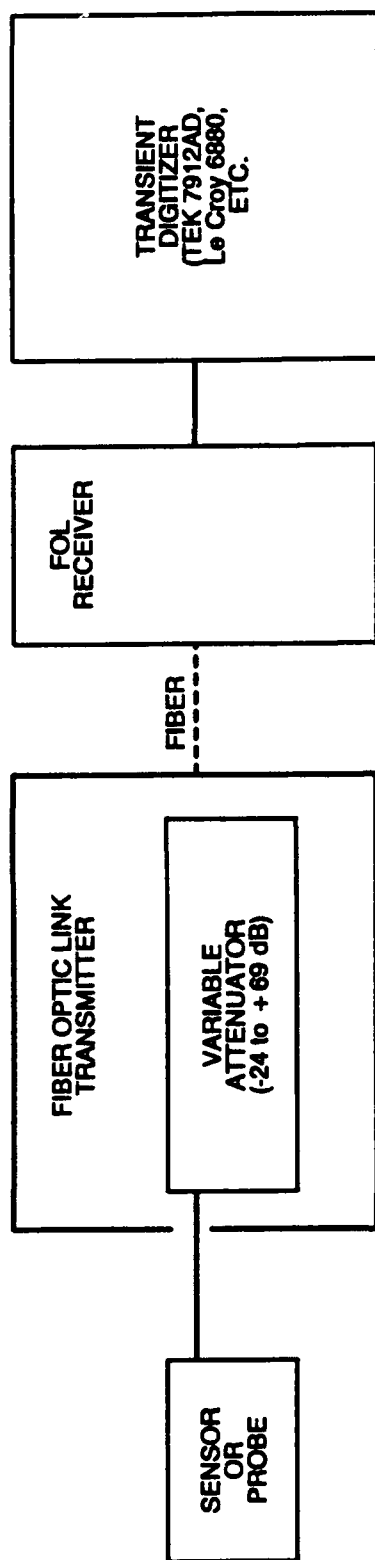


Figure 1. Typical EMP instrumentation.

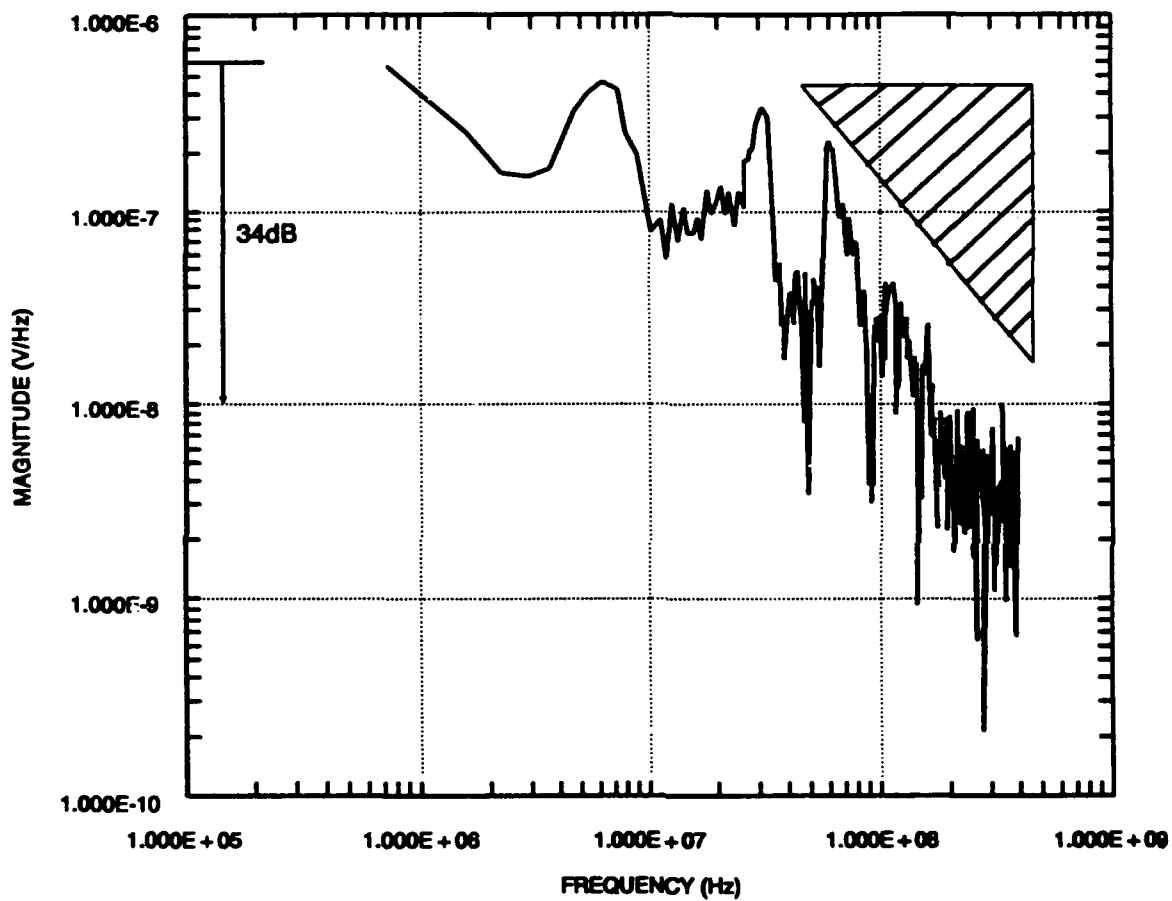


Figure 2. Typical raw frequency plot.

by link noise. In Figure 2, this appears to include most data above 100 MHz. This situation is typical for most EMP field and current data from most large test objects.

Two multipass/multichannel approaches are currently known to improve high-frequency signal-to-noise in EMP data; band-limiting techniques and so called "integrated/derivative" techniques.

Band-Limiting Techniques

In band-limiting techniques, data are acquired through a high-pass filter and again through a low-pass or no filter. This is accomplished in two shots by first using a high-pass filter and then using a low-pass or no filter. To acquire data with a single shot, two channels are "Tee'd" from a single sensor or probe. Data from the high-pass filter are Fourier transformed and frequency tied to the unfiltered or low-pass filtered data. This accomplishes the desired effect since link attenuation is separately adjusted for high- and low-frequency components, but the technique costs double time and equipment, and there are considerable numerical error sources from the frequency tie.

Integrated/Derivative Techniques

Integrated/derivative techniques can be used where the sensor or probe inherently produces the derivative of response data. Most field sensors and some current probes produce derivative output. With these techniques, one channel, or the data from one shot, acquires the waveform directly (the "derivative" channel), while a second channel, or data from a second shot, is acquired through an integrator which is placed ahead of the link. The "integrated" channel produces a replica of the waveform (integrated derivative data). In processing, the derivative measurement, which contains highly emphasized high-frequency components by nature, is numerically integrated, Fourier transformed, and high-band limited. The result is frequency tied to "integrated" channel data which have been Fourier transformed and low-band limited. Again, the desired effect is accomplished but at the expense of considerable time, equipment, and processing error.

THE PREEMPHASIS FILTER

The preemphasis filter is named for its similarity in function to a technique used in FM broadcasting used to reduce audible hiss (high audio frequency noise). Preemphasis in FM broadcasting boosts the high-frequency portion of the audio signal prior to transmission and restores the high end to original levels in the receiver using deemphasis filters. The deemphasis filters reduce hiss from atmospheric noise, but the high-end content of the audio is not apparently affected.

The EMP transient response data preemphasis filter works by reducing the low-frequency component (below 80 MHz) of EMP response data by 12-16 dB. This has the effect of relatively increasing (emphasizing) the high-frequency content by this amount. The signal-to-noise ratio in the low end is not affected because the dynamic range of the probe is very large (>100 dB) and can handle a 16-dB cut without ill effect.

Figure 3 shows an approximation of the original preemphasis filter specification. The EG&G company was able to adapt their "cable compensator" filter to meet the specifications. The specifications are submitted in units of "gain" to be compatible with vendor requirements:

"Unbalanced GR input and output connectors, 50-Ω input and output impedance, 6-dB gain at 60 MHz, 10-dB at 100 MHz, -16-dB gain at 200 MHz."

Figure 4 shows a sweep of the prototype filter. From the sweep, it is apparent that the region of preemphasis lies between 10 MHz and something over 2 GHz. The response of the filter falls off and is jagged above 1 GHz. A new version of the filter is currently planned that will hopefully flatten and extend this region.

Figure 5 compares raw unfiltered data (top) with raw filtered data (bottom). These waveforms were acquired by splitting the signal from an SCP-1 current probe through a passive "T", passing one side through the preemphasis filter (top trace) and an FOL, and passing the other side directly through another FOL (no filter). The noise floor of the links are shown on the plots as

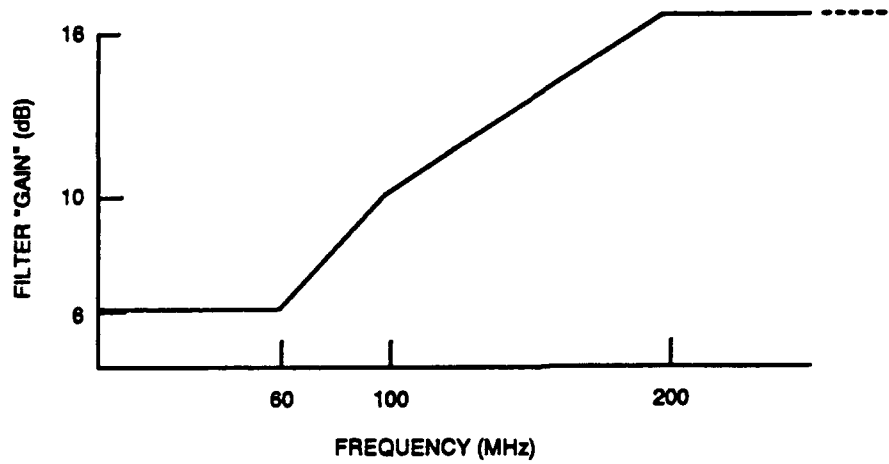


Figure 3. Approximation of original preemphasis filter specification.

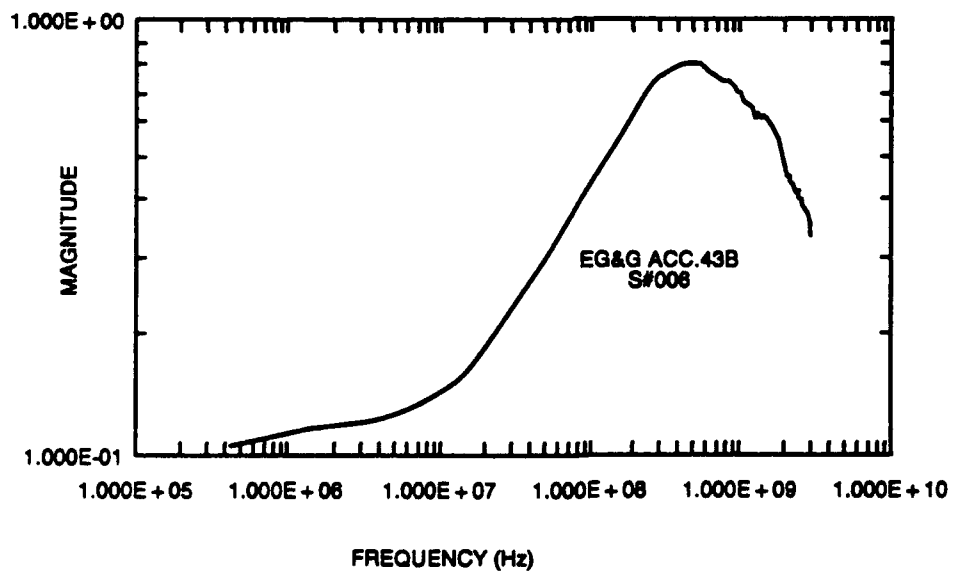


Figure 4. Sweep of the prototype filter.

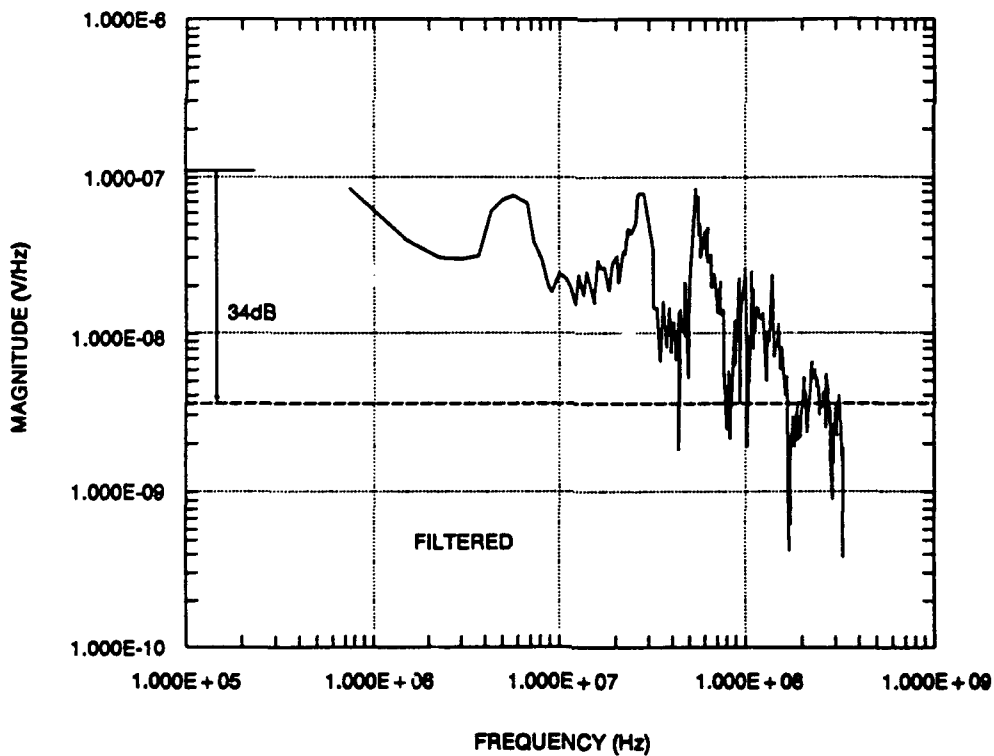
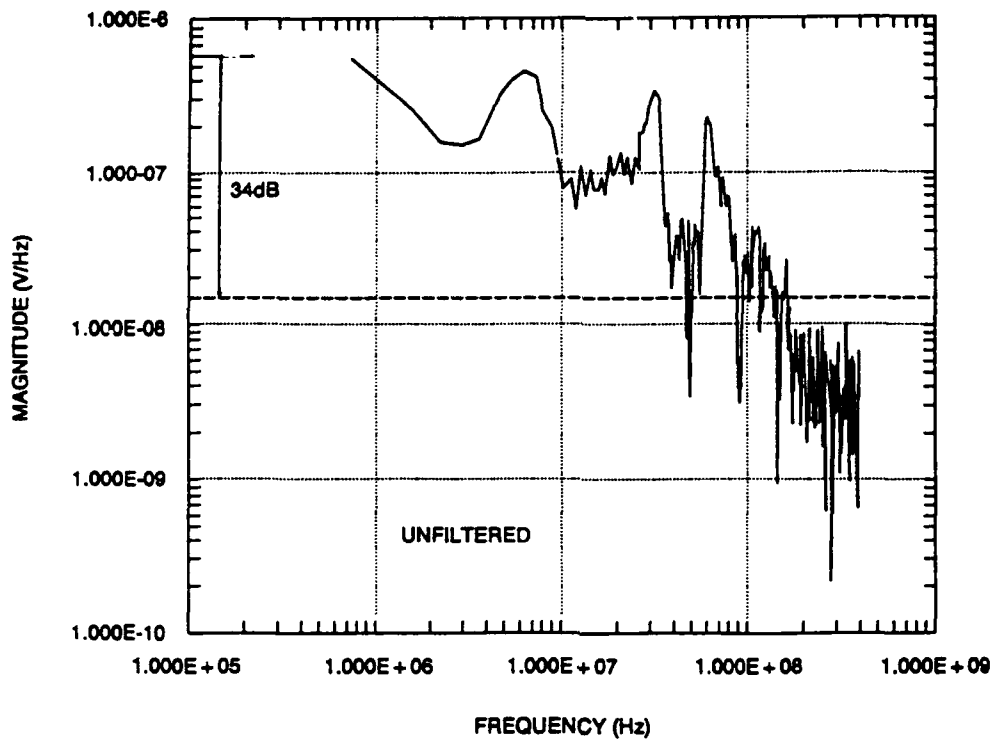


Figure 5. Comparison of raw unfiltered data (top) to raw filtered data (bottom).

dashed lines. The filtered data can be seen to have a greater portion of high-frequency content above the noise floor than the unfiltered data. Also, there is visibly less noise hash in the filtered data, particularly above 100 MHz, and there is visibly higher structure detail overall.

As with deemphasis in FM broadcasting, the high end of preemphasized data must be restored to the original level. For EMP data, this is done in processing by unfolding the transfer function of the filter along with transfer functions of the link, probe, and any other instrumentation in the channel. Figure 6 compares unfiltered and filtered data after processing. The greatest visual difference appears to be the greater positive and negative peaks on the initial cycle.

CONCLUSION

The broadband EMP transient measurement preemphasis filter has been demonstrated to improve the high end signal-to-noise ratio in representative EMP transient response measurements. Further effort is planned to improve the high-frequency characteristics of the filter and to explore other applications for the technique.

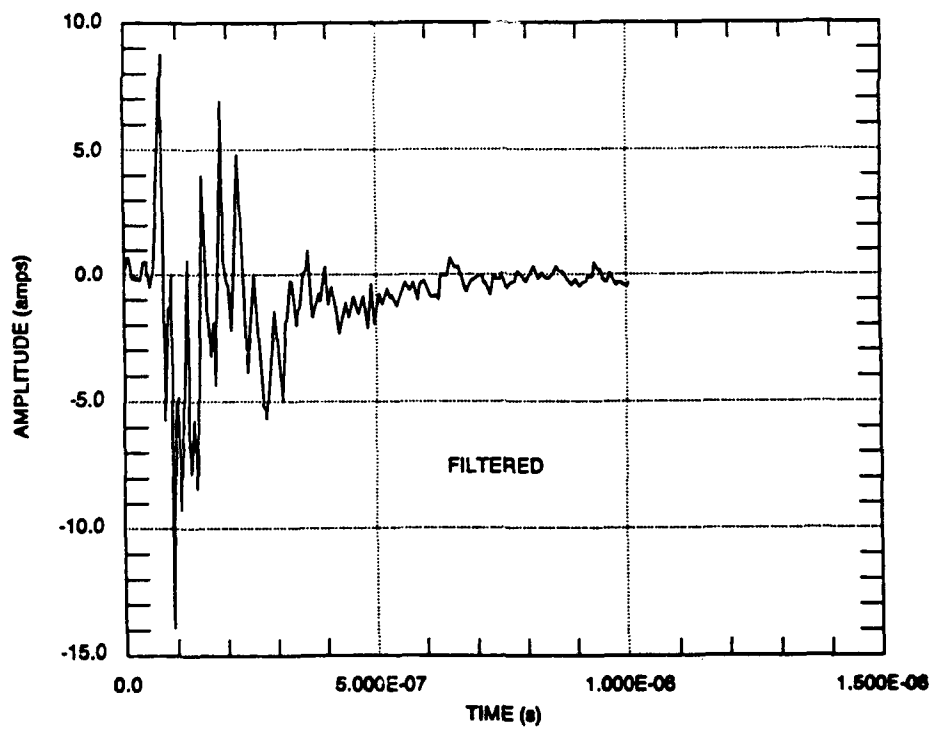
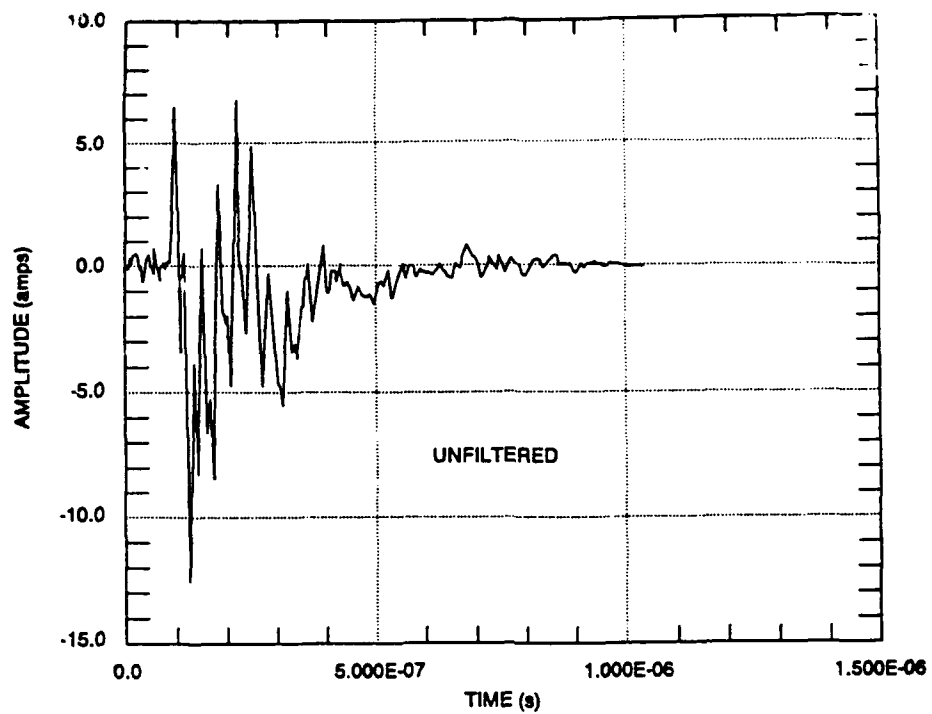


Figure 6. Comparison of processed unfiltered data (top) with processed filtered data (bottom).